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Opportunities for Growth Regulation of Amenity Grass*

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Abstract: Plant growth regulators have found applications in numerous crop situations but amenity turf provides a unique challenge. This paper discusses the major opportunities in this sector and reports results from trials carried out in the UK over four years with trinexapac-ethyl in a range of situations. The weight of clippings was reduced by 40% and absolute sward height by up to 21% compared to the untreated control; of more practical relevance for mown turf, this amounts to a reduction of up to 48% in clippings weight when the influence of height of mowing is taken into account. It is safe to a wide range of grass species. The data show considerable potential for this PGR as a management tool for amenity turf in Northern Europe.

Key words: trinexapac-ethyl, turf growth regulator, PGR, amenity turf, Levington Shortcut

1 INTRODUCTION

Plant growth regulators (PGR) have been used successfully in a large number of applications in agricultural crops. In general, the successful niches have been in single cultivars of large-scale annual crops such as cereals where, for example, a precisely timed application of an antigibberellin will uniformly reduce stem length, increase resistance to lodging and increase yield. An example of such treatments is chlormequat applied at growth stage 30–31 at 1·61 kg AI ha^{-1} to control lodging in wheat,[1] to achieve the best results from the PGR it was necessary to optimise fungicide and nitrogen inputs.

With high-value ornamental crops a similar, relatively straightforward, situation exists, where the objective is to reduce the extension growth of single varieties of plants such as chrysanthemums which have all been established from uniform plant material grown in a precisely controlled substrate and raised in a controlled environment.[2]

These situations contrast markedly with many of the opportunities for manipulating vegetation growth in amenity situations. Generally speaking, the greatest opportunities for growth regulation in this sector present the greatest biological challenge. For example, the control of roadside vegetation via use of plant growth regulators demands that a single application, of necessity at a single rate and timing, must effectively suppress the extension growth of an extremely wide range of species for as long as possible—preferable the entire growing season. Clearly this is very difficult when it has been firmly established that plant growth regulators need to be applied at a precise growth stage for optimum effect on individual species which will, in itself, depend upon the desired effect (cf. cereals and top fruit).[3]

A further complication in the roadside verge scenario is that a number of plant growth regulators, e.g. paclobutrazol, effectively suppress vegetative extension growth but do not suppress seedhead production.[4,5]

The overall effect of such applications can, therefore, only be less than perfect with currently available technology. There will inevitably be considerable variations in height and texture, and, over the longer term, the species composition may be affected.[5–7] Fortunately, the results in such situations are not generally subject to critical scrutiny by the customer and, indeed, some initial phytotoxicity may even be tolerable. Also, variations in height and species dominance may be perceived as a benefit, for example where wild flowers are encouraged, as long as the effect of the plant growth regulator

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is economically justified compared to such alternatives as mowing.

At the other extreme of the opportunities for plant growth regulators in amenity situations is the golf course green. The growing media for the plants which produce the playing surface range from variously modified local soils on classic links courses such as St. Andrews, through to sand-dominated greens constructed to the very precise USGA (United States Greenkeepers Association) specification. The grass species themselves range from classic European bent/fescue mixes through to the Penncross creeping bent often recommended in association with USGA specification greens. A large proportion of courses are 'contaminated' by grasses normally classified as weeds, particularly *Poa annua* L. It should, however, be noted that *P. annua* is the dominant species on the greens on some well-established high-quality courses and that, with appropriate management, a high class, year-round playing surface is still maintained.

In other parts of the world local grasses, e.g. Bermuda grass (*Cynodon dactylon* L.) and *Zoysia* spp, also give an acceptable playing surface.[8]

In the majority of situations, the expense of golf green construction means that they are designed for use over an indefinite period. Whilst particular varieties of desirable species will be sown initially, inevitably environmental conditions and management practices can dramatically influence the species composition over a period of time. Golf greens are, of course, intensively managed, receiving high levels of fertilization, irrigation and, where necessary, crop protection chemicals. In order to maintain the desired playing surface during the majority of the year they are cut on a daily basis—possibly more often during tournaments. They would seem, therefore, to offer a relatively straightforward niche for the use of plant growth regulators. Clearly, the application of a chemical which, from one application, could reduce the number of mowings required could be a cost-effective option when offset against the manpower and machinery costs of such operations. Unfortunately, to date no chemical has yet been able to overcome reliably the infinitely variable permutations identified briefly above for golf green applications.

Existing materials provide acceptable performance at the roadside verge end of the spectrum and the major opportunities for plant growth regulators in amenity turf situations, therefore, lie in the middle ground, i.e. fairways, roughs, sports fields, areas of amenity turf and in areas which are difficult to mow.

Both Watschke and DiPaola[9] and Kaufmann[10,11] have discussed the different types of plant growth regulators available. It is believed that there are three classes of PGR. Class A types, e.g. trinexapac-ethyl, interfere with the production of gibberellic acid late in the biosynthetic pathway and can be useful on the moderately to intensively, managed turf. Class B PGRs, e.g. flurprimidol and paclobutrazol, interfere with the production of gibberellic acid early in the biosynthetic pathway and can be used on moderately, to intensively managed turf but their use is limited by turf bronzing. Class C PGRs are mitotic inhibitors and prevent cell division, thus stopping new growth for a period. Seedhead suppression can be achieved with Class C PGRs but sward colour can be affected adversely. Examples of Class C PGRs are maleic hydrazide, mefluidide and amidochlor. By contrast, Kaufmann[11] split the PGRs into two groups, those suppressing growth with primary action as gibberellic acid biosynthesis inhibitors (Watschke and DiPaola's Classes A and B)[9] and those suppressing growth and development, i.e. Class C.

The active ingredient trinexapac-ethyl was reported in 1989[12,13] as CGA 163935, a new plant growth regulator for small grain cereals, oilseed rape and turf. Further work on its action was published in the UK in 1991.[14] Additional publications in the USA include work on root growth enhancement following application of trinexapac-ethyl.[15] This compound acts by suppressing the biosynthesis of gibberellic acid,[14,16] it is taken up by the foliage and translocated to the growing shoot where it affects internode elongation. Development of the plant continues and the new plant organs develop in miniature. However if a plant's growth is suppressed for more than six weeks it will begin to turn brown as old leaves die without new leaves to take their place.[17]

Trinexapac-ethyl, already introduced successfully into the USA and recently in France is now in the process of registration in the UK. It is proving to be a potent material and its positioning as a management aid, rather than as a conventional plant growth regulator, reflects a significant shift in the philosophy of use of such materials in amenity turf situations.

2 MATERIALS AND METHODS

2.1 Chemicals

The following chemicals were used:

Trinexapac-ethyl 250 g kg^{-1} WP in water-soluble sachet (registration applied for as 'Levington Shortcut', Levington Horticulture Ltd) applied at 300 or 400 g AI ha^{-1} in water at 500 litre ha^{-1}.

Mefluidide 240 g $litre^{-1}$ SL ('Mowchem', Rhône-Poulenc) applied at 400 g AI ha^{-1} in water at 1000 litre ha^{-1}.

Paclobutrazol 250/dicamba 25 g $litre^{-1}$ SC ('Holdfast D', Zeneca) applied at 1500/150 g AI ha^{-1} in water at 800 litre ha^{-1}.

2.2 Efficacy trials

A total of 25 experiments with trinexapac-ethyl were carried out in the UK by Levington Horticulture Ltd

between 1992 and 1994 and a further 15 are still in progress. The majority of these trials were carried out at Levington Research Station, Suffolk, UK but, as the programme has developed, these have been extended to give a good geographical spread within the British Isles. Some elements of the work have been carried out on contract by the Sports Turf Research Institute (STRI), Bingley, West Yorkshire, UK and a number of user trials are also in progress.

A randomised block design was used in setting out all efficacy trials. In 1993, trials had three blocks with a plot size of 3 m^2 (1·5 × 2 m); those in 1994 and 1995 had four blocks with a plot size of 3 m^2. In all trials at Levington Research Station, sprays were applied using a Hozelock Courier 4 sprayer. Mefluidide was included in trials as a control, in 1993 and paclobutrazol in 1994 and 1995. Changes in vegetation yield were measured in terms of fresh weight of mowings from three strips from each plot at a standard cutting height which depended on the species present. Changes in grass heights (mm) were measured using the Levington Research Station version of a rising disc apparatus taking the mean of four measurements per plot. Efficacy trials were also scored for sward colour, phytotoxicity, number of grass seedheads and evenness of retardation where appropriate.

The efficacy trial reported in Tables 1 and 2 was first sprayed in May 1994. Trinexapac-ethyl plots were resprayed at monthly intervals. Paclobutrazol + dicamba was applied once in May. The trial was on a mixed *Agrostis tenuis* Sibth. + *A. castellana* L. + *Festuca rubra* L. sward. Grass height was recorded on a weekly basis. The trial plots were mown monthly at 22 mm and the fresh weight of mowings was recorded.

The efficacy trial in Table 3 was first sprayed in April 1995 on a mixed *Agrostis* spp. *Festuca* spp. and *Lolium perenne* L. sward. Trinexapac-ethyl treated plots were resprayed at monthly intervals. Paclobutrazol + dicamba was applied once in April. The trial was mown monthly at 50 mm. By August the weather turned very dry and hot, no irrigation could be applied to the trial and the grass died. It should be noted that neither the trinexapac-ethyl plots nor the paclobutrazol + dicamba plots appeared to be better or worse in their resistance to the drought than the untreated plots.

2.3 Growth inhibition

Changes in the absolute height of the sward (A) following application of the treatments were determined using the following equation:

$$A = 100 - \left[\frac{\text{Height of Treated}}{\text{Height of Control}} \times 100\right] \tag{1}$$

In later trials it was decided that for mown swards the change in height would be more appropriately defined in terms of the relative sward height (R) using the following equations:

$$R = 100 - \left[\frac{(Hb_{\text{control}} - Hm_{\text{control}}) - (Hb_{\text{treated}} - Hm_{\text{treated}})}{Hb_{\text{control}} - Hm_{\text{control}}} \times 100\right] \tag{2}$$

where Hb and Hm are the heights before and after mowing, respectively.

$$= 100 - \left[\frac{Hb_{\text{control}} - Hb_{\text{treated}}}{Hb_{\text{control}} - Hm} \times 100\right] \tag{3}$$

Change in fresh weight was calculated using the following:

$$\text{Change} = \left[\frac{F_{\text{treated}}}{F_{\text{control}}} \times 100\right] \tag{4}$$

Where F_{treated} and F_{control} are the fresh weights of the treated and control plots, respectively.

2.4 Phytotoxicity

Phytotoxicity trials at Levington Research Station in 1994 and 1995 were laid out in a randomised block design with four blocks and 1 m^2 plots. STRI phytotoxicity trials had five blocks with 0·5 × 0·5 m^2 plots, with treatments applied by an Oxford Precision sprayer.

3 RESULTS

3.1 Fresh weight reduction

Table 4 shows the percentage reduction in fresh weight of clippings in comparable treatments over three years. Tables 1 and 3 give further details of the effects of trinexapac-ethyl on fresh weight in trials carried out in 1994 and 1995.

In summary, trinexapac-ethyl at 400 g AI ha^{-1} can give an average of 41% reduction in weight of grass clippings compared to an untreated control. Trials at Levington Research Station in 1994 gave 54 and 57% reduction. The actual degree of reduction will be dependent on the grass species present, as well as the fertilization, irrigation and maintenance of the sward.

3.2 Growth inhibition

Table 5 shows the influence of various treatments on the percentage reduction in height (Growth inhibition A) and Growth inhibition R compared to an untreated

TABLE 1
Influence of Growth Regulators on Cumulative Fresh Weight of Clippings Removed (Levington Research Station, 1994)

Treatment	*Rate* ($g\ AI\ ha^{-1}$)	*Cumulative fresh weight* ($kg\ m^{-2}$) *Weeks 1 to 24*	*Change in fresh weight*[a] (%)
Untreated control	0	1·155	0
Trinexapac-ethyl	400	0·61[b]	−47
Paclobutrazol + dicamba	1500 + 150	0·70[b]	−39
LSD (0·05)		0·19	

[a] Calculated using equation in Section 2.3.
[b] Significantly different from control at $P = 0{\cdot}05$.

control over a period of three years. Table 2 shows the effects of trinexapac-ethyl on grass height and growth inhibition A and R in more detail in a trial carried out in 1994. These data show that trinexapac-ethyl can give absolute growth inhibition (A) of up to 21% compared to an untreated control. For the mown turf situation this is more meaningfully described in terms of a relative reduction (R) of up to 48%.

3.3 Phytotoxicity to grass

Trials carried out in 1993 at Levington Research Station on mixed *Agrostis/Festuca* sward showed no phytotoxicity following one application of trinexapac-ethyl. Trials in 1994 and 1995 showed only minimal phytotoxicity following five applications of trinexapac-ethyl at monthly intervals. Trials in 1994 and 1995 on

TABLE 2
Influence of Growth Regulators on Sward Height over Time (Levington Research Station 1994)

Treatment	*Rate* ($g\ AI\ ha^{-1}$)	*Mean grass height (mm)* *Before treatment*	*Weeks after treatment*[a] *1*	*3*	*4*	*Reduction in height* A^b	*Growth inhibition* R^b
Untreated control	0	28·0	32·13	37·63	38·94	—	—
Trinexapac-ethyl	400	27·62	27·44[c]	29·25[c]	30·75[c]	21	48
Paclobutrazol + dicamba	1500 + 150	29·0	29·56	31·37[c]	34·63[c]	11	25
LSD (0·05)		2·69	2·83	2·83	3·72		

[a] Mowed on 3, 17 and 24 June 1994 respectively.
[b] Calculated using equations in Section 2.3.
[c] Significantly different from control at $P = 0{\cdot}05$.

TABLE 3
Influence of Growth Regulators on Fresh Weight of Clippings Removed at Monthly Intervals (Thorpe Park Golf Course, Peterborough, 1995)

Treatment	Rate ($g\ AI\ ha^{-1}$)	*Fresh weight* ($g\ m^{-2}$) *weeks after treatment*[a] *4*[b]	*8*[b]	*12*[b]
Untreated control	0	793 (0)	1760 (0)	334 (0)
Trinexapac-ethyl	400	511[c] (36)	1072[c] (39)	243[c] (27)
Paclobutrazol + dicamba	1500 + 150	652 (18)	1497[c] (15)	290 (13)
LSD (0·05)		161·7	182·4	59·6

[a] Clipping dates were 9 May, 6 June and 5 July, respectively.
[b] % Reduction in parentheses.
[c] Significantly different from control at $P = 0{\cdot}05$.

TABLE 4
Summary of Effects of Treatments of Turfgrass over a Three-Year Period[a,b] (Levington Research Station 1993, 1994, 1995 and Thorpe Park Golf Club, 1995)

Treatment	*Rate (g AI ha^{-1})*	*Change in fresh weight (%)*[a,b] 1993	1994	1995	Mean
Trinexapac-ethyl	400	−36	−45	−41	−41
Mefluidide	400	−49	nt[c]	nt[c]	−49
Paclobutrazol + dicamba	1500 + 150	nt[c]	−12	−23	−18

[a] Calculated using the equation in the text.
[b] Mowed four weeks after treatment was applied.
[c] Not tested.

L. perenne swards showed no phytotoxicity after five applications of trinexapac-ethyl at monthly intervals. Tables 6 and 7 show results of species-specific phytotoxicity tests done at STRI in 1994 and 1995. Small phytotoxic effects were noticed, particularly on *Agrostis* spp.

Three *Festuca rubra litoralis* cultivars, four *Festuca rubra* L. subsp. *commutata* cultivars, six L. *perenne* cultivars and *Festuca rubra* L. subsp. *rubra* cv. Cindy and Victor were also tested in 1994 with no phytotoxicity observed. It should be noted that no fertilizer was applied to the trial; also that only 1 h was left between mowing and the third monthly application of trinexapac-ethyl, possibly leading to an increased propensity to show phytotoxic effects.

Scorch was noted on all plots, including the untreated control, in July and early August, probably due to the

TABLE 5
Summary of Absolute (A) and Relative (R) Growth Inhibition Compared with an Untreated Control, Four Weeks after Treatment of *Agrostis/Festuca* and *L. Perenne* Swards at Levington Research Station with one of Three Plant Growth Regulators

Treatment	*Rate (g AI ha^{-1})*	*Growth inhibition (%)* A[a] 1992	A[a] 1993	A[a] 1994	A[a] Mean	R[a] 1994
Trinexapac-ethyl	400	13	19	21	18	48
Mefluidide	400	28	32	nt	30	nt
Paclobutrazol + dicamba	1500 + 150	9	nt	11	10	25

[a] Calculated using the equations cited in the text.

TABLE 6
Phytotoxicity Scores for Different Grass Species Treated on Three Occasions with Trinexapac-ethyl. (Sports Turf Research Institute, 1994)[a]

Treatment	*Rate (g AI ha^{-1})*	*Phytotoxicity*[b] Festuca rubra rubra *cv. Moncorde*	Agrostis tenuis *cv. Sefton*	Agrostis castellana *cv. Highland*	Agrostis stolonifera *cv. Penncross*	Poa pratensis *cv. Asset*
Untreated control	0	1·00	1·20	1·20	1·80	1·20
Trinexapac-ethyl	200	1·00	2·00	1·40	1·60	1·20
Trinexapac-ethyl	400	1·00	2·20	2·20	3·00	1·20
Trinexapac-ethyl	800	1·20	3·40	2·60	3·00	1·80
LSD		NS	0·75	0·76	0·76	NS

[a] Data relate to the score 65 days after the first treatment was applied on 4 November 1994, i.e. 10 days after Treatment 3.
[b] Scored on a scale 1–10 where 1 signified no damage and 10 death of the turf; > 4 is unacceptable.

TABLE 7
Phytotoxicity Scores for Different Grass Species Receiving Three Treatments with Trinexapac-ethyl (Sports Turf Research Institute, 1995)[a]

		Phytotoxicity[b]			
Treatment	*Rate (g AI ha^{-1})*	Agrostis tenuis *cv. Sefton*	Agrostis castellana *cv. Highland*	Agrostis stolonifera *cv. Penncross*	Poa pratensis *cv. Limousine*
Untreated control	0	2·25	4·25	3·50	3
Trinexapac-ethyl	400	3·75[c]	4·75	4·50	3·25
Trinexapac-ethyl	800	4·25[c]	5·50[c]	5·25	3·75[c]
LSD		1·43	0·91	1·35	0·72

[a] Treatments applied at monthly intervals; data refer to scores for the 99th day after the first (34 days after the third) treatment on 9 August 1995.
[b] Scored on a scale 1–10 where 1 signifies no damage and 10 death of the turf; > 4 is unacceptable.
[c] Significantly different from control at $P = 0{\cdot}05$.

hot weather, minimal fertilizer and little or no irrigation. By 99 days after the first treatment, only the *Agrostis* spp. and *Poa* spp. were affected. At the recommended rate for trinexapac-ethyl, the effect was only statistically significant on *Agrostis tenuis* Sibth.

Further trials are being carried out at Levington Research Station to study the effect of applying trinexapac-ethyl over a period of years. Following two years of applications with five monthly applications per year starting in May, no significant phytotoxicity has been observed on the mixed *Agrostis*/*Festuca* plots. Grass density was also unaltered.

3.4 Species composition

A further trial at STRI, detailed in Table 8, addressed the issue of change in species composition following application of plant growth regulators. In this trial, trinexapac-ethyl was applied three times at monthly intervals, starting in May, and paclobutrazol + dicamba was applied once in May. There were no significant effects.

4 CONCLUSIONS

These data show that trinexapac-ethyl offers a significant improvement as a turf grass treatment over existing growth regulators. Its effects are relatively short-lived, making it an ideal management aid with very flexible application regimes. Over the course of a season it can reduce the amount of clippings produced by more than 40%, giving significant savings on machinery and labour costs in high-maintenance turf situations. The fact that it does not suppress seedhead production is not relevant for most of the situations in which it will be used since, unlike most current materials, it is likely to be used in combination with mowing. In other situations, for example, difficult-to-reach areas, seedheads are not a major issue.

From the point of view of phytotoxicity trinexapac-ethyl is generally very safe. The only possible exception is on some *Agrostis* spp. cultivars. Observations in other parts of the world have shown that any tendency towards phytotoxicity is greater where fertility is low and weather conditions are cool. In the STRI phytotox-

TABLE 8
Percentage Species Composition of Mixed Sward before and after Treatment with Plant Growth Regulators (Sports Turf Research Institute, 1995)

		Composition (%)[a]					
		Pre-treatment (1 May 1995)			*76 days after treatment (7 July 1995)*		
Treatment	*Rate (g AI ha^{-1})*	Agrostis	Festuca	Poa	Agrostis	Festuca	Poa
Untreated control	0	59	27	12	65	27	7
Trinexapac-ethyl	400	61	27	10	62	27	12
Paclobutrazol + dicamba	1500 + 150	55	31	13	65	26	9
LSD		NS	NS	NS	NS	NS	NS

[a] Measured using an optical ten-point quadrant with 100 points.

icity trials reported here the level of fertility was very low. Further work needs to be carried out to investigate these phenomena in more detail.

There is no evidence so far that trinexapac-ethyl in any way influences the species composition of the sward. Ongoing experiments at Levington Research Station should provide confirmation that this continues to be the case after a number of years of application.

With experience of use of the chemical, experienced turf managers will identify numerous situations in which checking the growth of the grass by predictable amounts will be beneficial in their individual situations, for example, tees, fairways, roughs and areas which are difficult to mow, where labour is at a premium due to staff holidays, illness etc.

Trinexapac-ethyl is clearly a much more sophisticated management tool than its predecessors. It will take time in the hands of experienced turf managers before its full potential is realised since it is a product where unsophisticated use is likely to lead to disappointment.

The material therefore heralds a new dawn for plant growth regulators in amenity turf situations but its successful introduction is hampered by the fact that it will have to overcome the prejudices in the market place which are due to the failings of previous materials. However, the data presented in this paper indicate that, if used correctly, it will have a very bright future indeed.

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